EFFECT OF COALCHAR REACTIVITY AND REDUCTION TEMPERATURE ON THE REDUCTION BEHAVIOUR OF IRON ORE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Metallurgical & Materials Engineering

By
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&
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National Institute of Technology
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Under the Guidance of
Prof M. KUMAR

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CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF COALCHAR RACTIVITY & REDUCTION TEMPERATURE ON THE REDUCTION BEHAVIOUR OF IRON ORE**" submitted by Sri Abhisek Bose & Sri Dinkar Roy in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Metallurgical & Materials Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma**.**

Date:

Prof. M. KUMAR
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Abhisek Bose
Dinkar Roy

CONTENTS

ABSTRACT

In the present investigation , an attempt has been made to study the effect of coal char reactivity and reduction temperature on the reduction behaviour of iron ore pellet. The reduction tests were conducted in the temperature range of 900-950 degree centigrade. The parameters studies were the reduction temperature and coal char reactivity.The experiments were statistically designed such that the effect of each variable and interactional effect of each variable can be quantitatively assessed and compared.The results showed highest degree of reduction coal char having high percentage of fixed carbon content.

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CHAPTER-1

Introduction

INTRODUCTION

- Coaking coal reserves are limited in India. So industrialists are switching over from blast furnace route to direct reduction route

- In India the future of coal based direct reduction process is bright because of huge reserves of non-coaking coal.

- Presently there are approximately 150 sponge iron plants in India producing about 11.5 million tons of sponge iron per annum which is highest in the world.

- Reactivity of coal char is one of the important parameter affecting the rate of reduction of iron ore.

Objective:-

-Collection of coals from different mines of Orissa

-Preparation of chars

-To establish a relationship between reactivity & % degree of reduction of iron ore

CHAPTER-2

Literature Review

LITERATURE REVIEW

PELLETS: Pellets are approximately spherical lumps formed by agglomeration of the crushed iron ore fines in presence of moisture and binder, on subsequent induration at 1300°C.

MECHANISM OF PELLET FORMATION

1. Ball Formation – Surface tension of water & gravitational force creates pressure on particles, so they coalesce together & form nuclei which grow in size into ball.

2. Induration (Heat Hardening) – Solid state diffusion at particle surfaces at higher temperature cause recrystallisation & growth giving strength

Theory of ball formation-

When we add water ,water creates surface tension and capillary force on the particles.Due to combied effect of surface tension and gravitational force,the fine particles are bound together when falling from higher height to lower height and form a ball like structure by forming a nuclei which grow later.The ball like structures are called as balla(balls becom pellets after heat hardening)

Induration(Heat Hardenig)-

Actual strength of pellets is determined by allowing them to fall from a height f 2m ,so that they do not form fines.Induration is done to increase the strength of pellets to withstand a load of 200 kg.

Advantages of Pellets:

1. Good Reducibility

   Due to high porosity

2. Good bed Permeability

   Due to Spherical shape and open pores

3. High Strength (150-250 kg/cm2) or More

4. High Porosity (25-30%)

5. Less heat consumption than sintering

6. Uniform chemical composition

7. Easy handling and transportation

8. Good resistance to disintegration during furnacing

9. Resistance to weathering and freezing

Disadvantages of Pellets:

- High cost of Production

  Due to Grinding and firing cost

- Low Basicity (Max. - 1.2)

  So lime is charged externally

- Swelling and loss of strength of fluxed pellets

Due to moisture absorption by hygroscopic nature of lime

COAL-

It is a firm ,brittle, sedimentary combustible rock derived from vegetable debris. Coal is a nonrenewable energy source because it takes millions of years to create. The energy in coal comes from the energy stored by plants that lived hundreds of millions of years ago, when the earth was partly covered with swampy forests. For millions of years, a layer of dead plants at the bottom of the swamps was covered by layers of water and dirt, trapping the energy of the dead plants. The heat and pressure from the top layers helped the plant remains turn into what we today call coal.

Types of Coal-

1-Coaking coal

2-Non-coaking coal

Coal is classified into four main types, or ranks (lignite, subbituminous, bituminous, anthracite), depending on the amounts and types of carbon it contains and on the amount of heat energy it can produce. The rank of a deposit of coal depends on the pressure and heat acting on the plant debris as it sank deeper and deeper over millions of years. For the most part, the higher ranks of coal contain more heat-producing energy.

COAL CHAR

It is the carbonized of non-coking coal product at a temperature 900 degree centigrade or higher than this.

The burning rate of a char particle is governed by the rate of oxygen transfer to the surface of the burning char and by the actual rate of chemical reaction on the char surface (internal and external). If the particle is porous, then the rate of diffusion of oxygen through the porous medium is important.

REDUCTION REACTIONS

Reduction:

It is the ease with which oxygen can be removed from the ore.

Reactions-

Indirect Reduction Reactions-

$Fe_2O_3 + CO/H_2 = Fe_3O_4 + CO_2/H_2O$

$Fe_3O_4 + CO/H_2 = FeO + CO_2/H_2O$

$FeO + CO/H_2 = Fe + CO_2/H_2O$

Direct Reduction Reactions-

$Fe_2O_3 + C = Fe_2O_4 + CO$

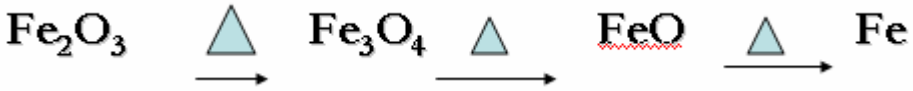
$Fe_3O_4 + C = FeO + CO$

$FeO + C = Fe + CO$

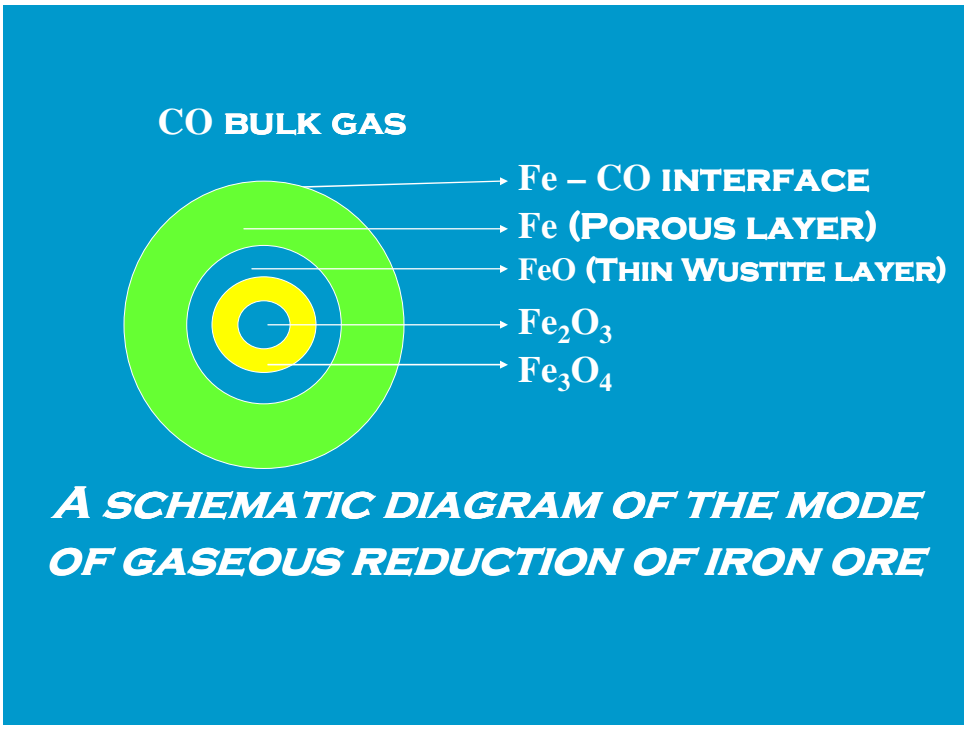
$3Fe + C = Fe_3C$

$C + CO_2 = 2CO$

In short:



(Fig-2.1)



Kinetic steps in Reduction of iron oxide

1.Transport of CO gas from bulk gas phase to Fe – CO interface

2. Molecular diffusion of CO gas through Fe layer to the reaction interface

3. Adsorption of the CO gas at the interface

4. Reaction between the Fe oxide & CO gas at the interface

5.Desorption of the product gas CO2 at the interface

6. Transport of iron & oxygen ions

7. Transformation in solid phase. Formation & growth of magnetite, wustite & iron

8. Diffusion of CO2 to surface

9. Desorption of CO2 gas from the Fe – CO interface to the bulk gas phase

Factors affecting Reduction Kinetics of Iron Ore Pellets

1-Temperature of Reduction
2-Time of Reduction
3-Particle Size of Iron ore
4-Pellet Size
5- Presence of Catalyst
6- Reactivity of Solid Carbon
7- Chemical nature of oxide
8- Fe_2O_3/C ratio

When iron ore pellets are being reduced by coal chars,the above factors are affecting the rate of reduction .However,our experiment varied the following 2 factors keeping other factors constant.

1-Temperature of Reduction
2-Reactivity of Solid Carbon

CHAPTER-3

Experimental

EXPERIMENTAL

Collection of Raw Materials:-

- Iron ore was collected from BPJ PMC LIMITED NO. 6 iron ore mine of Orissa.
- The chemical analysis of this iron ore is given in Table-1.
- Coals used for making chars were procured from 14 different coal mines of Orissa, as cited in Table-2.

Table -3.1 Chemical analysis of BPJ OMC Ltd. NO.-6

Iron ore	Total Fe (%)	Fe2O3 (%)	Al2O3 (%)	SiO2 (%)	TiO2 (%)	Loss on Ignition (%)
BPJ OMC Ltd. No.-6	91.8	62.7	4.09	3.80	0.11	2.43

Preparation of Coal Chars

- The chars for the reduction studies were made by carburization of these coals at a temperature of 950 degree centigrade (soak time-1.5hr).
- A known weight of coal powder of size -72 mesh was taken in a stainless steel reactor covered with a lid. A hole was made in the lid for the escape of volatile material.
- The reactor was introduced into the muffle furnace & heated from room temperature to the required temperature of 950 oC& kept there for 1.5 hr followed by furnace cooling.
- The chars were then taken out & processed for reduction studies.

Pellet Preparation

- Iron ore pellets were made from BPJ OMC LIMITED NO. 6 Iron ore fines of size -100 mesh.
- The pellets (approximately spherical in shape) were made by hand rolling of moistened iron ore fines.
- The pellets thus obtained were dried in an air oven at a temperature of 110 degree centigrade for 2 hours & then indurated at a temperature of 1200 degree centigrade for 1 hour followed by furnace cooling

Reactivity Measurement

- Studies on CO2 reactivity of these chars were carried out by Professor M. KUMAR as per Indian Standard method.
- These data were utilized in our study to find a co-relation between degree of reduction & reactivity of coal chars.

Reduction Studies

- Reduction studies of fired iron ore pellets (size-15-16mm approximate) in coal chars were carried in a stainless steel reactor (size- H(10.0 cm)& D(5.0 cm)).
- The reactor was made half full with coal char powder of size -72 mesh & the weighed (oven dried) pellet was placed centrally on this coal char bed & the remaining portion of the stainless steel reactor was filled with coal char powder The reactor lid had a hole centrally for the escape of the gas.
- The reactor was then introduced into the furnace & heated from room temperatur to the required temperature of 900 oC & soaked there for 1 and 1.5 hour respectively.
- The reactors were then taken out & cooled in air. The weight losses in pellets were recorded by an electronic balance & calculation for % reductions were made.

Degree of Reduction

The % reduction was calculated by using the following formula-

Degree of Reduction(%)=

(weight loss in pellet/total oxygen present in the pellet) x 100

CHAPTER-4

Result & Discussion

RESULT & DISCUSSION

Table-4.1 Results for the reduction studies of BPJ OMC Ltd No.-6 Iron ore

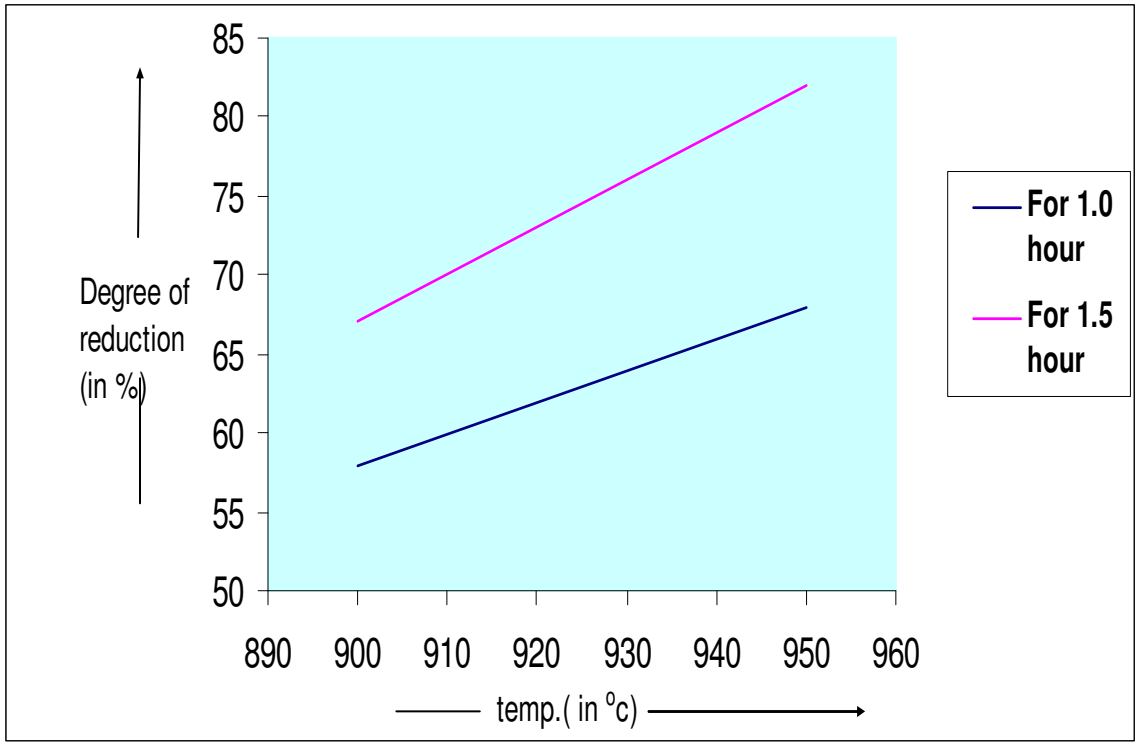
Coal char	**Temperature of Reduction in °C**	Time of Reduction (in hours)	Degree of Reduction (in %)	**Reactivity (in cc/g.min)**
NANDIRA	900	1.0	40.85	3.12
		1.5	46.43	
BHARATPUR	900	1.0	50.50	5.44
		1.5	79.78	
LAKHANPUR	900	1.0	67.89	9.30
		1.5	82.896	
ORIENTOR-2	900	1.0	59.75	5.17
		1.5	69.02	
ORIENTOR-4	900	1.0	41.38	12.36
		1.5	60.21	
BASUNDHARA PH-7	900	1.0	41.73	3.62
		1.5	53.53	
SAWALESWARI	900	1.0	65.80	6.39
		1.5	78.30	

Coal char	Temperature of Reduction in °C	Time of Reduction (in hours)	Degree of Reduction (in %)	Reactivity (in cc/g.min)
RKC	900	1.0	54.82	3.66
		1.5	61.88	
ANANTA	900	1.0	57.69	5.88
		1.5	81.03	
LINGARAJ	900	1.0	76.42	3.50
		1.5	65.61	
BASUNDHARA PH-2	900	1.0	58.57	4.41
		1.5	72.35	
JAGANNATH	900	1.0	49.84	2.16
DHERA	900	1.0	53.85	7.81
		1.5	64.03	
BEPAHARH	900	1.0	58.00	4.67
		1.5	67.00	

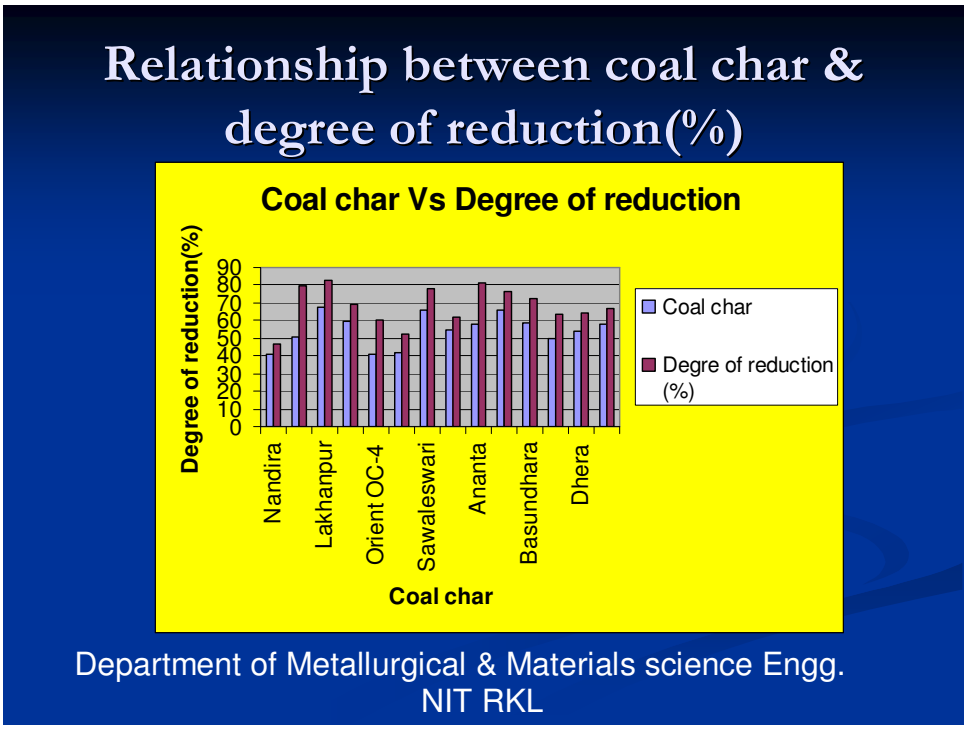
Results for the Reduction studies of BPJ OMC LIMITED Iron ore pellet in coal chars (Table-4.2)

Coal :- Belpaharh		
Reduction temperature (in ^{O}C)	Time of Reduction (in hrs.)	Degree of Reduction (in %)
900	1	58
	1.5	67
950	1	68
	1.5	82

Results for the Reduction studies of BPJ OMC LIMITED Iron ore pellet by coal chars (Fig-4.1)



(Fig-4.2)


Relationship between coal char & degree of reduction(%)
Coal char Vs Degree of reduction
Degree of reduction(%)
90
80
70
60
50
40
30
20
10
0
Nandira
Lakhanpur
Orient OC-4
Sawaleswari
Ananta
Basundhara
Dhera
Coal char
Coal char
Degre of reduction (%)
Department of Metallurgical & Materials science Engg.
NIT RKL

(Fig-4.3)

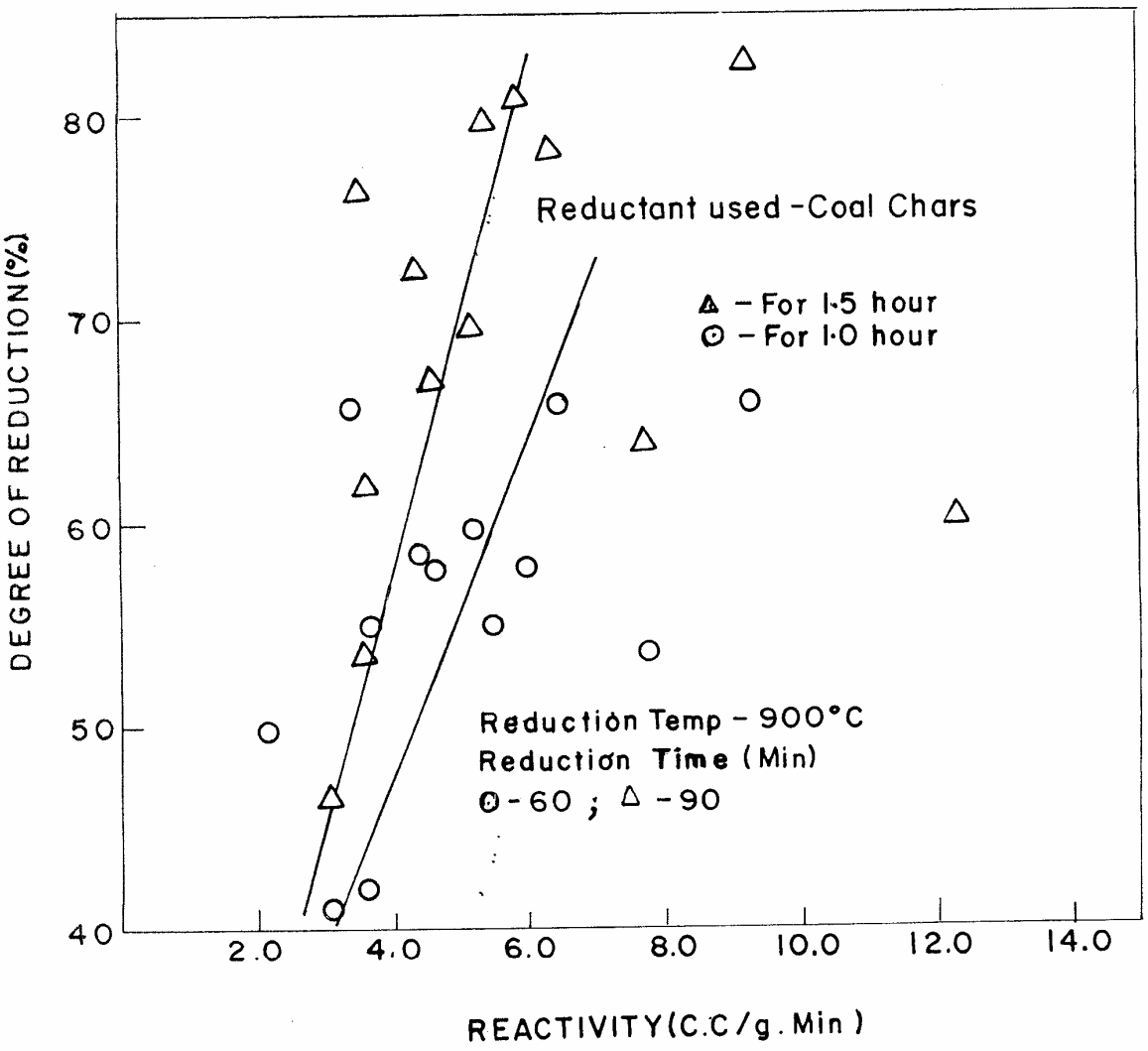


Fig. Relationship Between Degree of Reduction (%) and Reactivity of Coal chars.

The degree of reduction goes on increasing with increase of coal char reactivity. The reduction temperature used for the experiment is 900 degree centigrade .Reduction time for circular plots is 60 minutes and that for triangular plots is 90 minutes.

CHAPTER-5

Conclusion

CONCLUSION

- With some scattering of data, the % reduction in general was found to increase with increase of reactivity of coal char.

- 2 or 3 coal chars ,inspite of having higher reactivity have shown lower degree of reduction(fig-4). This appears to be due to lower fixed carbon contents in their coal chars.

- With also increase of reduction temperature the percentage degree of reduction goes on increasing.

Scope of the future work

- Characterization of all these coal chars for their proximate & ultimate analysis

- To find a relationship between fixed carbon content & % reduction

- The reduction study with these coal chars may be extended for other iron ores also.

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